POPULATION DYNAMIC AND EFFECTS OF THE INVASIVE SPECIES CTENOPHORE *MNEMIOPSIS LEIDYI* IN THE SOUTHERN CASPIAN SEA

By

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LIST OF ABBREVIATIONS

Abbreviation	Description
APHA	American Public Health Association
DO	Dissolved Oxygen
NO_2	N- Nitrite
NO_3	N- Nitrate
N-Total	Total Nitrogen
NH_4	Ammonia
SiO_2	Silicate
P-total	Total phosphorus
P-organic	Organic phosphorus
sp	Species
SD	Standard Deviation
CSRIE	Caspian Sea Research Institute for Ecology
IFRO	Iranian Fishery Research Organization
CEP	Caspian Sea Environmental Programme

LIST OF SYMBOLS

Symbol	Description
°S	Degrees south
°N	Degrees North
°C	Degree Celsius
%	Percentage
mL	Milliliters
m^3	Cubic meter
m^2	Square meter
g	Gram
mg	Milligram
m	Meter (depth)
µg/L	Microgram/Liter
t	Ton
ppt	Parts Per Thousand
km^2	square kilometer
kg	Kilogram
$ind.m^{-3}$	Individual per cubic meter
$g.m^{-3}$	geram per cubic meter
µM	micromolar
$µg\ L^{-1}$	Microgram per Liter
ind.L-1	individual per Liter
$mg.L^{-1}$	Milligram per Liter
rpm	Rounds Per Minute

DINAMIKA POPULASI DAN KESAN SPESIES PENYERANG CTENOPHIDAE *Mnemiopsis leidyi* DI SELATAN LAUT CASPIAN

ABSTRAK

Penyerang “Ctenophore” *Mnemiopsis leidyi* (Agassiz A. 1965) yang dibawa daripada Laut Hitam ke Laut Caspian pada penghujung tahun 1990-an telah memberi kesan negatif kepada ekosistem di Laut Caspian. Dalam kajian ini, populasi *M. leidyi*, kelimpahan plankton, biojisim dan komposisi spesies serta interaksi antara persekitaran dan aspek biologi telah dikaji di persisiran pantai Laut Caspian, Iran pada tahun 2001 hingga 2006. Kelimpahan purata dan biojisim *M. leidyi* adalah tinggi pada peringkat awal serangan (iaitu, 641 - 1056 ind.m^{-3} dan 41.5 - 44.3 g.m^{-3}, masing-masing, dalam tahun 2001), dengan nilai tertinggi dicatat pada bulan September tahun 2001 (iaitu 753 ± 529 ind.m^{-3} dan 55.1 ± 54.7 g.$m^{-3,}$,masing-masing), dan nilai minimum pada bulan Julai dengan 283 ± 455 ind.m^{-3} dan 13.9 ± 21.4 g.m^{-3}, masing-masing. Musim pembiakan *M. leidyi* bermula pada bulan Julai, mencapai kemuncak pada bulan September, dilanjutkan sehingga bulan Oktober, dan menurun secara mendadak pada bulan November dan bulan Disember (kelimpahan purata: 232 ± 239 ind.m^{-3} dan biojisim: 13.6 ± 12.8 g.m^{-3}). Secara keseluruhannya, biojisim dan kelimpahan *M. leidyi* adalah lebih tinggi pada bulan bercuaca panas (bulan Ogos dan bulan September) berbanding dengan bulan bercuaca sejuk (bulan Januari hingga bulan April) di selatan Laut Caspian. Di keseluruhan kawasan kajian, juvenil (bersaiz kurang daripada 5mm) dan larva *M. leidyi* merangkumi 85.7% manakala

individu bersaiz 5 hingga 10mm mencatat 6.76% daripada jumlah keseluruhan. Individu dewasa (bersaiz lebih 50mm) hanya mencatat 1% daripada jumlah keseluruhan, dengan individu yang terbesar didapati berukuran 70mm panjang.

Sejumlah 18 spesies mesozooplankton (13 spesies adalah larva organisma bentik) dan holozooplankton (4 spesies Copepoda dan 1 spesies Cladocera) telah dikenalpasti. Jumlah bilangan spesies zooplankton yang dijumpai adalah 50% kurang daripada kajian lepas yang dijalankan di kawasan yang sama, sebelum *M. leidyi* diperkenalkan di kawasan perairan tersebut. Terdapat 24 spesies Cladocera, 7 spesies Copepoda dan 5 spesies merozooplankton di dalam kajian mereka. Spesies holozooplankton daripada kumpulan Cladocera kelihatan lebih dipengaruhi oleh serangan *M. leidyi*, di mana hanya satu spesies, *Podon polyphemoides*, masih berada di kawasan kajian. Bagi kumpulan Copepoda pula, *Eurytemora minor*, *E. grimmi*, *Calanipeda aquae dulcis* dan *Acartia tonsa* banyak ditemui sebelum serangan, dan selepas serangan *M. leidyi* hanya

A. tonsa (“copepodites” dan dewasa) mendominasi kawasan perairan di pedalaman dan persisiran pantai. Sepanjang tempoh kajian, nilai maksimum bagi kelimpahan zooplankton (22088±24840 ind.m^{-3}) dan biojisim (55.1± 54.7 mg.m^{-3}) telah direkodkan pada bulan Disember tahun 2001 dan bulan Ogos tahun 2004. Keseluruhannya, nilai purata kelimpahan zooplankton dan biojisim adalah 7015 - 11959 ind.m^{-3} dan 32.8 - 57.6 mg.m^{-3}, masing-masing, di mana nilai yang dicatatkan adalah 2 hingga 5 kali ganda kurang dari nilai purata yang dilaporkan pada tahun 1996. Dengan merujuk kepada taburan “spatial” zooplankton, populasi maksimumnya diperhatikan berada di kawasan di mana biojisim *M. leidyi* adalah rendah. Dalam data jangkamasa panjang, terdapat sedikit pertalian antara populasi *M. leidyi* dengan mangsa utamanya, zooplankton, dan faktor persekitaran seperti suhu, saliniti dan kepekatan nutrien.

POPULATION DYNAMIC AND EFFECTS OF THE INVASIVE SPECIES CTENOPHORE *MNEMIOPSIS LEIDYI* IN THE SOUTHERN CASPIAN SEA

ABSTRACT

The invasive ctenophore *Mnemiopsis leidyi* (Agassiz, A. 1965) which was transported from the Black Sea into Caspian at the end of 1990s has negatively affected the ecosystem of the Caspian Sea. In this study, *M. leidyi* population, plankton abundance, biomass and species composition and interaction between environmental and biological characteristics were evaluated in the Iranian coasts of the Caspian Sea from 2001 until 2006. The mean abundance and biomass of *M. leidyi* were high in the earlier period of invasion (641 - 1056 ind.m^{-3} and 41.5 - 44.3 g.m^{-3}, respectively, in 2001), with highest value in September 2001 (753 ± 529 ind.m^{-3} and 55.1 ± 54.7 g.m^{-3}, respectively), and minimum values in July with 283 ± 455 ind.m^{-3} and 13.9 ± 21.4 g.m^{-3}, respectively. *M. leidyi* production started from July, reached a peak in September, extended until October, and sharply decreased in November and December (mean abundance: 232 ± 239 ind.m^{-3} and biomass: 13.6 ± 12.8 g.m^{-3}). As a whole, the biomass and abundance of *M. leidyi* were significantly higher in the warmer months (August and September) than in the colder months (January to April) in the southern Caspian Sea. Over the whole research area, small individuals (smaller than 5 mm) and larvae of *M. leidyi* amounted to 85.7%, whereas those from 5 to 10 mm amounted to 6.76%. The largest individuals (greater than 50 mm) comprised only 1%; the largest individual was 70 mm in length.

A total of 18 mesozooplankton (13 species as larvae of benthic animals) and holozooplankton (4 Copepoda and 1 Cladocera) species were identified from the study area. The total number of zooplankton species found here was 50% less than a previous investigation performed in 1996 in the same region, which was before the introduction of *M. leidyi*. A total of 24 Cladocera, 7 Copepoda and 5 merozooplankton species reported in the previous study. Cladocera species seemed to be highly affected by the *M. leidyi* invasion, where only one species *Podon polyphemoides* remained in the monitoring stations. While Copepoda *Eurytemora minor*, *E. grimmi*, *Calanipeda aquae dulcis* and *A. tonsa* were abundant before *M. leidyi* invasion, only *Acartia tonsa* (copepodites and adults) dominated at the inshore and offshore waters after the invasion. The maximum zooplankton abundance (22088 ± 24840 ind.m^{-3}) and biomass (64.1 ± 56.8 mg.m^{-3}) were recorded in December 2001 and August 2004 during the study period. Overall, mean zooplankton abundance and biomass were 7015 - 11959 ind.m^{-3} and 32.8 - 57.6 mg.m^{-3}, respectively, which were 2 to 5 fold less than the mean values reported in 1996. With respect to the spatial distribution of zooplankton, maximum population was observed in regions where *M. leidyi* biomass was low. Long-term data showed that there were more or less positive relations among *M. leidyi* population, their main prey organism zooplankton and some environmental factors such as temperature, salinity and nutrient concentrations.

CHAPTER 1

INTRODUCTION

The Caspian Sea is a lake with no outlets, which is washing shores of five countries: Azerbaijan, Iran, Turkmenistan, Kazakhstan and Russia (Figure 1). it is located on a vast continental depression on the border between Europe and Asia, between $47^o07'$ and $36^o33'$ and $45^o43'$ of eastern longitude. The level is 28.3 m below the World Ocean's level; its fluctuation depends on the water balance. If the balance is positive then the level rises, if negative it decreases (Aladin and Plotnikov, 2004). The Caspian Sea is the largest inland water body in the world, with a surface area of about 380,000 km^2 (the northern area 25%, middle 36% and Southern area 39%) and a volume of approximately 78,000 km^3. The coastal length of the sea is about 6,380 km. It measures 1200km from north to south and 200–450 km from east to west. The Southern Caspian Sea coast (Iranian part) is 900 km (Dumont, 1995). Therefore, the study was conducted in the Southern Caspian Sea (Iranian coasts) in six transects located at $48^o57'$ N and $36^o40'$ E at 5, 10, 20, 50 and 100 m depths from 2001 to 2006.

In the early 1980s, the comb jelly *Mnemiopsis leidyi* abundant that normally resided off the eastern United States, was accidentally introduced into the Black Sea via ballast waters from cargo ships. This voracious zooplanktonic predator (with extremely high rates of reproduction and growth) reached enormous biomass levels (a few hundred million tons for the entire basin) devastating the pelagic food chain in the entire Black Sea basin by the end of 1980 (Vinogradov *et al*., 1989).

Inevitably, such high biomass of this comb jelly consumed a considerable fraction of the zooplankton that had been the food for pelagic fish and their larvae before its invasion. One of the dramatic consequences of the *M. leidyi* invasion was the sharp drop (from about 630,000 tons in 1988 to steadily 150,000 tons in 1991) in commercial catches of planktivorous fish (mainly the anchovy *Engraulis encrasicolus* L.) in the Black Sea (Kideys, 1994; Prodanov *et al*., 1997). The yearly economical damages to the fisheries sector alone were estimated to be about USD 250-500 million during this period (Kideys, 1994).

A warning that *M. leidyi* might also invade the Caspian Sea had been voiced during the Geneva meeting as well as by Dumont (1995). Unfortunately, at the end of the 1990s the invasion of *M. leidyi* in the Caspian Sea was already being reported (Ivanov *et al*., 2000; Roohi, 2000; Esmaeili *et al*., 2000; Roohi *et al*., 2001). It must have also been transported in the ballast waters of ships traveling from the Black Sea (salinity 18 ppt) to the Caspian Sea (maximum salinity 13-14 ppt) through the Volga Don Canal. Investigations in the Caspian Sea showed that by September 2000, *M. leidyi* was found everywhere including the northern Caspian where the salinity can be as low as 4 ppt (Shiganova *et al*., 2001a).

The impact of *M. leidyi* on the Caspian Sea ecosystem has been even worse than in the Black Sea due to the greater sensitivity of this enclosed basin. Adverse impacts from *M. leidyi* could be listed as the following:

1) The fish population collapse was the most apparent problem in the ecosystem. Significantly decreases were observed in the pelagic (mainly sprat *Clupeonella spp*.) fishery of all countries bordering the Caspian Sea: almost 50% decrease in the kilka catches of both Iranian, Azerbaijan and Russian fisheries had occurred during 1999 and 2001 (Fazli and Roohi, 2002). During spring and summer of 2001, mass reduction (estimated as 250,000 tons, or 40% of the population) of sprat were reported at the sea surface (Shiganova *et al*., 2004). The fish catch value was halved again in 2002, resulting in great economic losses. Fishermen even stopped fishing during most part of 2003, due to lack of fish (Kideys *et al*., 2004).

2) Sharp decrease in fish catch became a big problem for thousands of people earning on livelihood from sprat fishery. The economical loss from sprat fishery alone is hundreds of million Euros per year. Not only pelagic fishes, but also some large predators feeding on these fish such as white sturgeon *Huso huso* and the endemic Caspian seal *Phoca caspica* are also suffering from significant population decrease. The mass deaths of Caspian seals (*Phoca caspica*) occurred in the northern Caspian Sea during the spring of 2000 (Shiganova *et al*., 2003). Significant decreases in pregnancy and fat content in seal population were also reported. The white sturgeon, that is famous for the quality of its caviar, mainly depends on sprat as food (Shiganova *et al.,* 2003; Shiganova *et al*., 2004).

3) Biodiversity of the Caspian is important as most of species occur only in this sea (i.e. endemic species). Not only the abundance of zooplankton

but also the species composition is reported to decrease sharply. For example, the number of zooplankton (copepod and cladocerans) species during 2001-2002 was only three species compared to 22 species in 1996. The consequences of such reduction could be very significant for the ecosystem (Roohi *et al*., 2003).

The precious Caspian ecoystem is in a catastrophic condition due to an invasive jellyfish species (the ctenophore *M. leidyi*). Due to the decrease levels of zooplankton, eutrophication (too much plant production) started to be a significant problem for this ecosystem (Kideys *et al*., 2004).

Objectives of the study

With respect to the geographical location, morphology, bottom topography, salinity and temperature regime, aquatic balance, and biological productivity, the South Caspian sharply differs from other parts of the sea. As it is a deep-water area, it contains slightly over 64% of the total water volume, but its total annual riverine runoff is less than 1% of the total riverine inflow into the Caspian (Salmanov, 1999). In the South Caspian, the majority of the world reserves of sturgeon are concentrated here (more than 90% according to data from the 1970s).

Due to the special importance of this area of the Caspian, particularly for Iran, we carried out a specific investigation to study the pattern of distribution of the new invader–ctenophore *M. leidyi* in the South Caspian and to reveal the factors assisting its invasion in this basin and limiting its distribution there. In addition, it should be determined the extent of the *M. leidyi* impacts on the habitat and different trophic levels of the pelagic ecosystem. The purpose of this study was to reveal the relationship between different environmental characteristics and the *M. leidyi* distribution. The hydrochemical parameters, species composition, abundance and biomass of phytoplankton and zooplankton were analyzed. Therefore:

The objectives of this study are:

(i) to study population dynamic of the ctenophore *M. leidyi* in the southern Caspian Sea from 2001 to 2006.

(ii) to determine the factors affecting the distribution and quantitative characteristics of the ctenophore *M. leidyi*.

(iii) to determine the impacts of the ctenophore *M. leidyi* on phytoplankton, zooplankton and fishes.

CHAPTER 2

LITERATURE REVIEW

2.1 Physical environment of the Caspian

Because of the variability of Caspian Sea levels, its area is also variable. The Caspian is meridiannally elongated. According to data published by Zonn (2000), its length makes 1225 km. The greatest breadth of the Caspian from the east to the west is 566 km, at Absheron to peninsula its breadth is only 204km. The average breadth from the west to the east makes 330 km. The surface is equal to 436 000 km^2, and volume is about 77000 km^3. The maximum depth of the Caspian is 1025 m, and the average depth is 184 m.

The Caspian Sea is divided into three areas, approximately equal parts: Northern, Middle and Southern. However, the volume of each area is extremely different from each other.

The Northern Caspian is the shallowest, and its area makes to about 29% of the entire area of the sea, though its volume makes less than 1%. According to Zonn (2000), the area of the Northern Caspian varies from 92750 up to 126596 km^2, and its average volume makes 900 km^3. The average depth is 6 m, maximal depths do not exceed 10 m, and about 20% of the area has the depth less than 1 m.

The area of the Middle Caspian makes up about 36%, and its volume is about 35% of the sea. According to Zonn (2000), the area varies from 133560 up to 151626 km^2, and the average volume makes 26400 km^3. The average depth is about 175 m, and the greatest at 790 m.

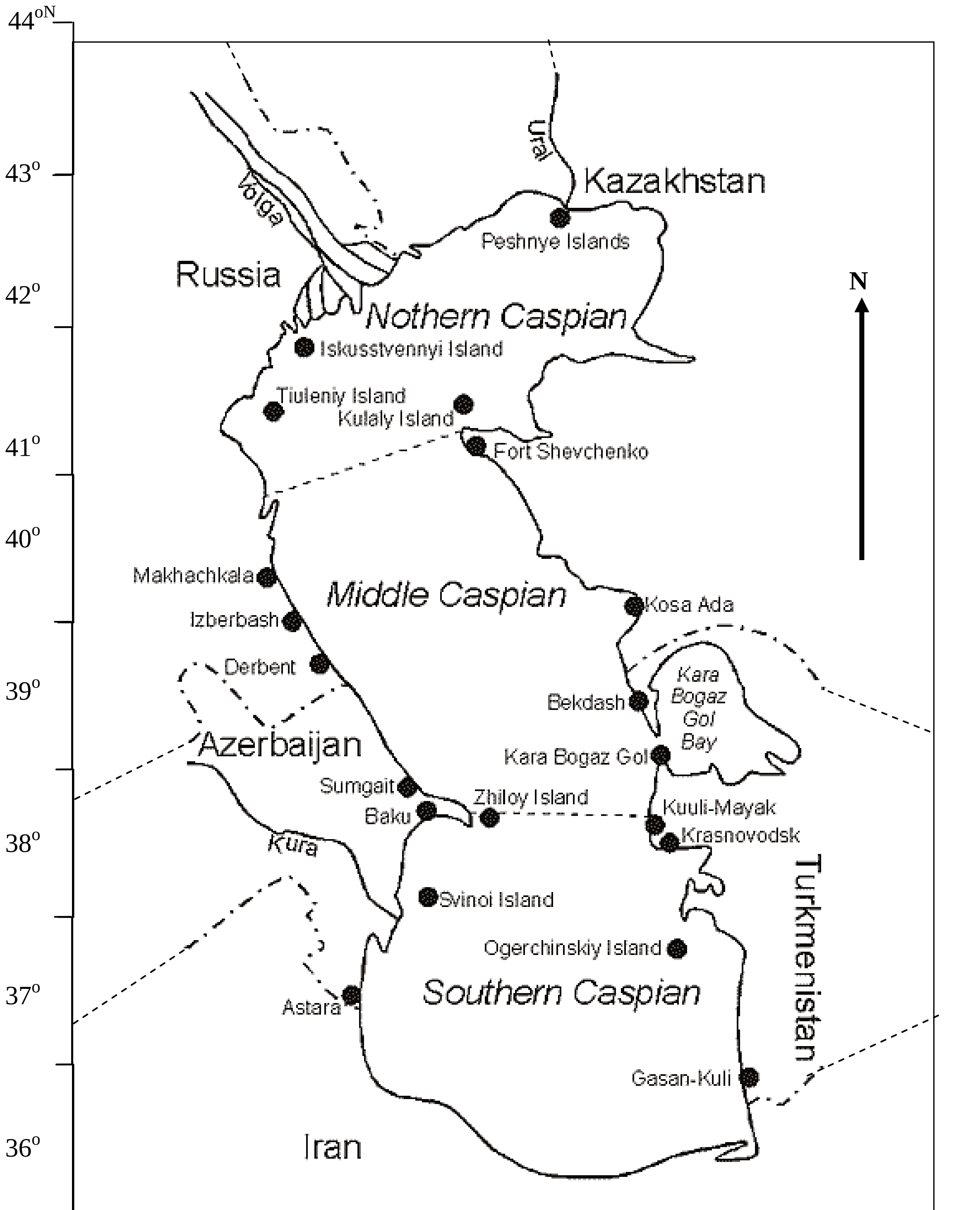


Figure 1.1 The Caspian Sea water area (modified from Rodionov, 1994).

The Southern Caspian has the largest volume - some 64% of the total volume, and its area amounts to 35% of the total area of the sea. It is the deepest part of the sea with the maximum depth reaching 1025 m. According to Zonn (2000), the area is from 144690 up to 151018 km^2, and the average volume 48300 km^3. The average depth is 300 m.

2.2 Some General characteristics of the Caspian Sea Waters

2.2.1 Water temperature: Water temperature is subject to considerable latitudinal changes, which are more distinct in winter time, when the water temperature changes from 0-0.5^{o}C at the edge of ice sheet in the north to 10-11^{o}C in the south i.e. difference in water temperatures up to 10^{o}C. The water temperature at western coast is higher than eastern coast by 1-2^{o}C. The water temperature in open sea is higher than in coastal regions: by 2-3^{o}C in the Middle Caspian and by 3-4^{o}C in the South Caspian (Kosarev and Yablonskaya, 1994).

In winter time, temperature distribution with depth is more homogenous, which is encouraged by hiemal vertical circulation. Water temperature lowers to the freezing point in northern part of the Caspian Sea and in shallow bays at eastern coast in moderate and severe winters (Kosarev and Yablonskaya, 1994).

Springtime warming of water levels evens up horizontal gradients and the difference in temperatures between coastal and open extents of the sea does not surpass 0.5^{o}C (Kosarev and Yablonskaya, 1994). Warming of the surface layer disturbs the homogeny in distribution of temperatures as per depth. Horizontal homogeny in temperature distribution in the surface layer is typical of summertime: in the middle parts of the sea 24-25^{o}C, in Southern parts 25-26^{o}C, in the southeast 27- 28^{o}C. The maximal water temperature is observed in August (Kosarev and Yablonskaya, 1994).

Every year, an upwelling occurs at eastern coast of the Middle Caspian in summertime resulting in a drop of surface water temperatures (7-15^{o}C). Formation of a layer with temperature starts in open extents of the Sea by the end of May or the beginning of June. It is more conspicuous in August. Often, it is located between horizons of 20 and 30 m in the middle of the Caspian and 30-40 m in the south. This layer rises close to the surface in the middle of the Caspian due to water retreats at eastern coast (Kosarev and Yablonskaya, 1994).

In autumn, under intensive cooling, the layer wears off and disappears by the end of November. In open sea, water temperature in the surface layer decreases in the middle part up to 12-13^{o}C and in the south – up to 16-17^{o}C (Kosarev and Yablonskaya, 1994).

Seasonal temperature changes are significant in the upper 100m-layer. Throughout a year the water temperature in bottom layers constitutes 4.5^{o}C in the Middle Caspian and 5.8- 5.9^{o}C in the South Caspian (Kosarev and Yablonskaya, 1994).

2.2.2. <u>Salinity</u>: Water salinity undergoes particularly sharp changes across northern part of the sea: from 0.1‰ in estuaries of the rivers Volga and Ural to 10-12‰ at the border with the Middle Caspian. There are insignificant salinity fluctuations in the Middle and South Caspian. Water salinity mainly constitutes 12.6-13.0‰ and increases in southward and eastward direction. In shallow bays, the water salinity increases to 20‰. Salinity insignificantly increases with water depth (0.1 – 0.2‰) (Aladin and Plotnikov, 2004; Kosarev and Yablonskaya, 1994).

2.2.3 Transparency: The waters of the Caspian Sea are characterized by high transparency. The most transparent area is the open waters of the Southern Caspian. In the Middle Caspian, the transparency of open waters is a little bit lower. In the Northern Caspian, because of the large inflow river drifts, the transparency is very low and is usually less than 1 m, and only at a great distance from the deltas, the transparency increases up to 7-8 m (Kosarev and Yablonskaya, 1994).

2.2.4 River flow and Nutrients: The Volga (80%), the Ural (about 5%), the Terek, the Sulak, the Samur (in total up to 5%), and the Kura (about 6%) are the main affluent of the Caspian. The riverine runoff from the Iranian coast, small streams from the Caucasus Mountains and other rivers amounts to 4-5% of the total runoff (Kosarev and Yablonskaya, 1994).

The trophic level and primary production of the Caspian Sea is low. The majority of nutrients brought in the Caspian with waters of the tributaries and, first of all, the Volga. Initially, nutrients used to come into the Caspian mainly in late spring or early summer. However, when the rivers became regulated (mainly the Volga), numerous dams detain and include in circulation of river reservoirs a part of nutrients (dissolved and suspended), which leads to a sharp decrease in the amount of phosphorus and silicon coming into the Caspian (Kosarev and Yablonskaya, 1994). Huge extents of the deltas are covered with macrophyte thickets. These macrophytes detain nutrients running into the Caspian (Aladin and Plotnikov, 2004; Kosarev and Yablonskaya, 1994).

Levels of nutrients in the Caspian Sea are low, even in the Northern Caspian, which is the most productive and richest part of the sea (Aladin and Plotnikov, 2004). Eutrophic conditions are observed only in some regions adjacent to the delta of the Volga. Levels of nutrients in the Middle and Southern Caspian arrive at the expense of an internal recirculation and with small runoff of rivers flowing first into the Middle Caspian and then Southern Caspian and also with rains. Thus, it is incorrect to name the Caspian a rich lake with high productiveness. The Caspian Sea is a poor lake in terms of production; only the Northern Caspian is not more productive (Aladin and Plotnikov, 2004).

2.3 Phytoplankton and Zooplankton of the Caspian

The Caspian Sea is a sea that contains unique flora and fauna, including many endemic species. Zenkevich (1963) published the first good report on fauna and flora of the Caspian Sea in 1963. According to this data, 718 species inhabit the Caspian: 62 species of protozoa, 397 species of invertebrates, 79 species of vertebrates (totally 476 species of free-living Metazoa), and 170 species of parasitic organisms. Of these species, some 46% were endemics of the Caspian Sea, 66% inhabit also the adjacent Southern seas, and 4.4% were of Atlantic and Mediterranean origins and 3% of Arctic origins. A total of 315 species and subspecies were registered in the zooplankton of the Caspian Sea (Kasimov, 1987, 1994); of these 135 species referred to infusorians (Agamaliev, 1983;

Bagirov, 1989). The majority of zooplankton species was of Caspian origins. The species composition of zooplankton of the Northern Caspian amounts to about 200 species. Infusoria were represented most diversely (more than 70 species). Rotatoria (> 50 spp.), Cladocera (> 30 spp.), and Copepoda (> 20 spp.) are less diversely represented (Kasimov, 1997).

The total number of phytoplankton species recorded during 1962–1974 period in the Caspian Sea was 449 (Kosarev and Yablonskaya, 1994; Proshkina-Lavrenko, 1963; Proshkina–Laverenko and Makrova, 1968). These species comprised of 163 diatoms, 139 Chlorophytes, 102 Cyanophytes, 39 Dinofagellates, 5 Euglenophytes and 1 Chrysophyte while the number of phytoplankton species decreased from the north (414 species) to the middle (225 species) and south (71 species) zones mainly due to the disappearance of fresh water forms towards the south. Diatoms and Pyrrophyta are dominant in the Caspian Sea. These two groups have an important role in primary production in this sea (Salmanov, 1987; Kasimov and Bagirov, 1983; Kasimov, 1987; Ganjian and Hossieni, 1998; Ganjian and Makhlogh, 2003; Ganjian *et al*., 2004a; Ganjian *et al*., 2004b).

The list of zooplankton animals of the Caspian Sea included 265 taxons of 6 groups. It consisted of Ciliophora–138 species, Sarcodina (Rhizopod)–4 species, Hydrozoa–4 species, Ctenophora–1 species, Rotifera–53 species, Cladocera–39 species, and Copepoda–26 species. This list did not include temporary plankters, larvae of bottom animals – mollusks, worms, and crustaceans. The list was based on published information in famous works dedicated to water fauna of the Caspian Sea during the period of 1960s-1980s (Birstein *et al.*, 1968; Mordukhai and Bolotovskaya, 1987). Only a small part of all plankton species was represented in previous materials prepared under the Caspian Environment Programme. The 1980s fundamental monographs were dedicated to specific taxonomic groups – Infusorium and predatory Cladocera. Thus, the total composition of planktofauna of the Sea has not been specified during several ten years.

Therefore, there is an urgent need to formulate the Southern Caspian flora and fauna species checklist. For the purpose of formulating the species checklist, a group of Iranian specialists has been conducting some researches (*e.g*. Rezvani *et al*., 1991; Hossieni *et al*., 1996; Laloei *et al*., 1999; Roohi *et al*., 2001; Kideys *et al*., 2001b; Bagheri and Kideys 2003; Kideys and Moghim, 2003) which included experts on every environmental aspect. This information was based on national reports on biodiversity and literary sources (mostly in local publications).

Data from Hossieni *et al*. (1996) showed that there were 46 planktofauna (78% holoplankton and 13% meroplankton) in the Southern Caspian Sea which belonged to Cladocera (52.1%), Copepoda (14.5%) and Rotatoria (10.4%), the rest were meroplankton such as Bivalve and Balanidae larvae. They reported that maximum zooplankton species composition was Cladocera and high frequency from Copepoda groups. There was a gap in investigation on Southern Caspian fauna due to shortage of facilities and fundamental plan in 1995- 1998. Until in 1998, Laloei *et al*. (1999) carried out a short-term survey of planktofauna in the coastal zones of Southern Caspian Sea (below 10 m) and reported almost the same results as the previous data.

2.4 Introduced species into the Caspian Sea

The effect of introduced species on the biological diversity of the Caspian Sea falls into two groups: chronic (long term) or acute (short term). Acute impact is identified during first years after the introduction of the new species into the Caspian. Its positive or negative impact is highlighted most clearly during these years. Later the ecosystem adapts to the introduced species, and its positive or negative effect weakens while its impact on the biodiversity becomes chronic (long-term) (Aladin and Plotnikov, 2004).

All present resident species in the Caspian can be described as introduced species. The only difference is the time of introduction. Some of the species were introduced so long ago that now some of the species can be considered 100% resident species.

Aquatic organisms of the Caspian can be divided into four groups. The first group is the most ancient introduced species. A scientific name for them is indigenous. Their ancestors lived 20,000,000-30,000,000 years ago and were the descendants of the ParaThetis inhabitants. As the ParaThetis was a huge northern bay of the ancient ocean Thetis, all aquatic life was introduced from Thetis. Thus, Caspian indigenous species are the descendants of ancient introduced organisms from the presently non-existing Thetis. Therefore, indigenous Caspian species are called ‘living fossils’ (Aladin and Plotnikov, 2004).

The second group is Arctic introduced species. A scientific name of the species is glacious relicts. The ancestors of the species were introduced into the Caspian 1,000,000-1,500,000 years ago during the period of melting of a huge ice sheet that covered almost all Europe, Arctic and coastal areas of the Baltic and the White Seas (Aladin and Plotnikov, 2004). The northern species reached the Caspian with melted waters. There are several opinions about the way the species reached the Caspian that were reviewed by Grosswald, 1980; Dawson, 1992. Scientists believed that a super flood occurred during the late Valdai period. The level of the ancient Caspian rose by 2-3 m above the level of the oceans of the world (Lamb, 1977), and its waters run through the Azov-Black Sea basin. Waters of a large ice lake that existed in the West Siberian Plain run into Aral basin and from Aral into the ancient Caspian.

The third group includes introduced species from the Black and Mediterranean Seas. Their scientific name is 'Atlantic introduced species'. The most ancient of the species were introduced into the Caspian 50,000 years ago during Khvalyn period (Zenkevich, 1963). The ancient Caspian was then connected with Azov-Black Sea basin through the Manych channel. Seven species were introduced into the Caspian in a natural way including *Zostera nana*, *Cardium edule*, *Fabricia sabella*, *Atherina mochon pontica*, *Syngnathus nigrolineatus*, *Pomatoschistus caucasicus* and *Bowerbankia imbricata* (Zenkevich, 1963). Some scientists (Fedorov, 1958; Fedorovich, 1987; Starobogatov, 1994) denied natural introduction of the species into the Caspian, as they believed that strong current in the Manych channel had always been directed away from the Caspian. If this point of view is correct, 50,000 years ago a first anthropogenic impact on the biodiversity of the Caspian would be recorded.

In the 20th century, the amount of introduced species from the Black and the Mediterranean Seas suddenly increased. All cases of introduction were related to anthropogenic activity (Kosarev and Yablonskaya, 1994; Aladin and Plotnikov, 2004). In 1920s, four species were accidentally introduced into the Caspian: algae *Rhizosolenia calcar-avis*, bivalve *Mytilaster lineatus*, and two species of shrimps: *Leander squilla* and *L. adspersus* (Aladin and Plotnikov, 2004). There was no reliable information about the way the species were introduced. Scientists suggested that merchants, who transported their small wooden boats on carts from the Azov Sea to the Caspian, could introduce them (Aladin and Plotnikov, 2004). The four species could be introduced with Azov water that remained in the boats, or in cages with living fish (Aladin and Plotnikov, 2004). During the first years following introduction, the abundance of the species was quite high; they suppressed the Caspian species. For instance, in 1936 the biomass of algae *Rhizosolenia calcar-avis* was several millions tonnes which was about 65% of the total plankton biomass (Kasimov and Bagirov, 1983). Following the 'biological wave', the abundance of the species reduced; an acute phase of impact on the biodiversity of the Caspian turned into a chronic one. A short rise of abundance and further reduction was recorded for bivalve *Mytilaster lineatus*, and the two species of shrimps. Later people deliberately introduced five more species into the Caspian. These included two species of mullet (*Mugil auratus, M. saliens*), one species of flounder (*Pleuronectes flesus luscus*), one species of Polychaeta (*Nereis diversicolor*), and one species of bivalves (*Abra ovata*). All the species adapted to the conditions of the Sea, and after a first abrupt rise the abundance stabilized and became a part of the ecosystem of the Caspian. In the middle of the 20th century, after the Volga-Don channel has been built, a new group of species was introduced into the Caspian (Aladin and Plotnikov, 2004). Some of them were introduced in ballast water of vessels; others were attached to the bottom of vessels. The following species were introduced with ballast waters: Crustacean (*Pleopis polyphemoides*), jellyfish (*Blackfordia virginica*), four species of algae (*Ceramium diaphanum*, *C. tenuissimum*, *Ectocarpus confervoides* f. *fluviatilis* and *Polysiphonia variegata*) and crab (*Rhithropanopeus harrisi*). The following species were introduced with biofouling: sea acorns (*Balanus impovisus* and *B. eburneus*) and one species of pearlwort (*Membranipora crustulenta*). Only barnacles had a rise in abundance while it was not so obvious for other introduced species. Introduction of Atlantic species into the Caspian through the Volga-Don channel continues. Only two plankton species (*Calanipeda aquae dulcis* and *Acartia clausi*) and Ctenophore (*Mnemiopsis leidyi*) were introduced into the Caspian with ballast waters at the end of the 20th century (Aladin and Plotnikov, 2004, Ivanov *et al*., 2000; Roohi, 2000). The first two species can be an example of a positive introduction as they are used as a food base by plankton-feeding fish and increase the value of the Caspian zooplankton. As for the Ctenophore, this species is an example of a negative impact on the biodiversity of the Caspian (Ivanov *et al*., 2000; Roohi, 2000, Esmaeili *et al*., 2000). The species eats zooplankton and causes starvation for the plankton-feeding fish. There is an opinion that the Ctenophore can cause complete loss of Caspian population of sprat (Aladin and Plotnikov, 2004; Fazli and Roohi, 2002). If this happens, the Caspian seal will also be lost.

The fourth group includes species introduced from fresh waters. As the above-mentioned species, they were introduced into the Caspian long ago, so they can be divided into ancient and recent species. The most ancient introduced species are Caspian gastropods that were originated from fresh waters of Pliocene (Aladin and Plotnikov, 2004).

The distribution of the above four main groups of the Caspian species varies with the different sections of the Caspian. Thus, 75% of species in the Middle and South Caspian are Caspian indigenous organisms, 20% are fresh water species, 3% are Atlantic introduced species, and 2% are Arctic species. A proportion of the species in the North Caspian is different (Aladin and Plotnikov, 2004). Fresh water species dominate here. The proportion of them is 60%, Caspian indigenous species are 36%, and Atlantic species are 4%, Arctic species – less than 1% (Aladin and Plotnikov, 2004).

2.4.1 The ctenophore *Mnemiopsis leidyi* in the Caspian Sea

2.4.1.1 Classification of Ctenophora

Currently about a hundred species are known, which are traditionally split into the classes of Tentaculata and Nuda (also known as Atentaculata).

- The Tentaculata make up by far the largest number of species; as their name implies, they possess tentacles, although these are sometimes vestigial. They are divided into the following six orders: (Agassiz, 1860).
    - Cydippida, which includes the sea gooseberry (*Pleurobrachia pileus*)
    - Platyctenida
    - Ganeshida (probably larval form)
    - Thalassocalycida
    - Lobata
    - Cestida, which includes the Venus' belt (*Cestum veneris*)
- The Nuda class contains only a single order, Beroida, to which the melon jelly (*Beroe gracilis*) belongs. As again the name of the taxon implies, they are distinguished by the complete absence of tentacles.

Due to the continued uncertainty over the ordering of ctenophora it is currently unclear whether the above divisions correctly reflect the actual phylogeny of the taxon. Molecular genetic studies indicate that cydipidda is a polyphyletic group, i.e. it does not include all the descendents of their common ancestor, and so the overall classification of the group needs to be revised.

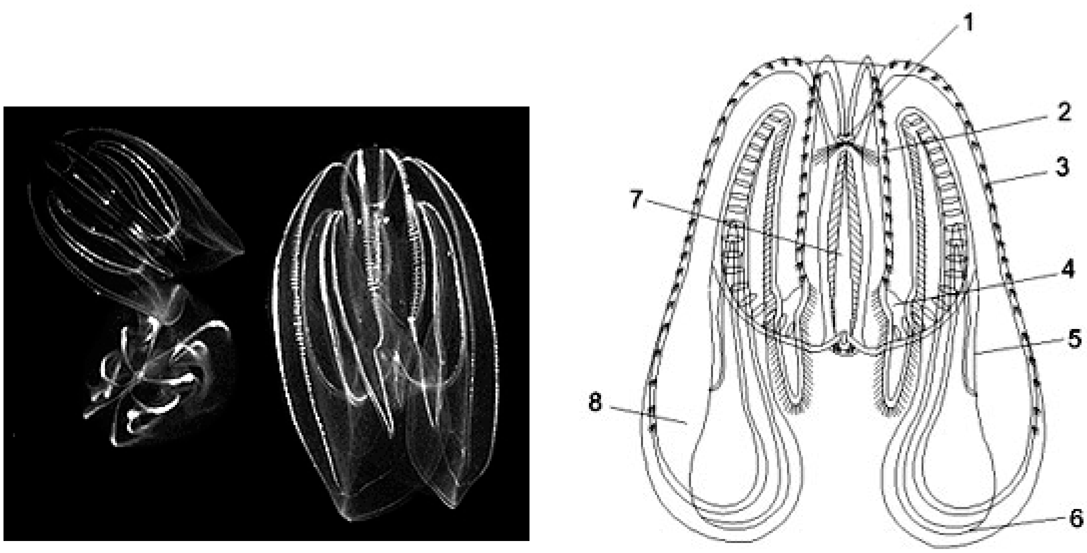
The following diagram shows the putative phylogeny of ctenophora on the basis of morphologic and molecular genetic data (RNA): (Agassiz, 1860).

Ctenophora
|--Cydippida (Mertensiidae family)
|--Platyctenida

|--Cydippida (Pleurobrachidae family)
|--Nuda Beroida
|--Cydippida (Haeckeliidae family)
|--Lobata
|--Cestida
|--Thalassocalycida

2.4.1.2 Figure and Taxonomy of *Mnemiopsis leidyi*

Phylum: Ctenophora Esch
Class: Tentaculata Chun
Order: Lobata Esch
Family: Mnemiidae Ech.
Genus: *Mnemiopsis* L.Agassiz; *Mnemiopsis leidyi* (A.Agassiz) 1965
Synonyms: *Mnemiopsis gardeni* L. Agassiz, 1860; *M.mccradyi* Mayer, 1912.
Common names: Russian: *Mnemiopsis*; English: *comb-jelly Mnemiopsis*



A) B)

Figure 2.1 *Mnemiopsis leidyi* of the Caspian Sea

A) in side view and B) morphological characteristics (1) aboral organ, (2) subtentacular row of comb flappers, (3) subsagital row of comb flappers, (4) auriculus, (5) subsagital tube, (6) translobal tube, (7) tentacular tube, (8) lobe (from Shiganova *et al*., 2001a).

2.5. Taxonomic description of *Mnemiopsis leidyi*

Mnemiopsis leidyi is the lobate ctenophore. Two oral lobes are derivatives of the ctenophore body (spherosome). Four smaller lobes -auricules are situated under the principal two oral lobes. During their movements the lobes in fold completely its buccal orifice. The oral lappets carry tentacular rings. Its central part is situated above the lips of the mouth crevice. Both "lips" are extremely contractible (Agassiz, 1860; Seravin, 1994). They have a pronounced lappet in its middle part, which prolongs into the distal end of pharynx canal. Around the outer end of both "lips" four labial (orifice) metalabile canals are passing being formed by bifurcated distal ends of the pharynx canal (Fewkes,1881). The tentacular apparatus is situated above the mouth lip. The tentacular bulb composed on two lobes is protected by tentacular bulb with a kind of two-lapped hood. The hood is contractible. The branches (bunches) of filamentous tentacles pass through the special canals to the mouth lip and between the ctenophore body (sphaerosoma) and the lobes. The plane passing via the central part of the sphaerosome and aboral apex divides the animal per two symmetrical parts. Along its both sides the meridianal canals pass. Under these subtentacular canals the subtentacular comb flappers are situated.

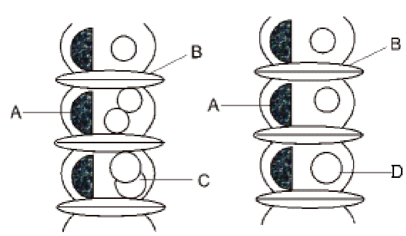


Figure 2.2 Morphology of *Mnemiopsis leidyi* gonads A) Meridianal, B) Past of gonad, C) Ovary and D) Testis (Fewkes, 1881)

The plane perpendicular to the latter is named as sagital. The subsagittal canals or tubes, under which rows of the subsagital comb flappers are situated, frame them. The meridianal canals end with the auricule canals, over which the auricule comb flappers are situated. Between the subtentacular and auricular flapper rows always is an interval. From the double lobed tentacular apparatus along the sides of animal's body the branches of the fine tentacles (tentilles) are protruding via special furrows. Their ends came out stretching to the mouth lip. Their ends form an extremely efficient catching apparatus between the internal surface of the side lobes and the sphaerosoma surface (Agassiz, 1860; Seravin, 1994). The tentacles are armed with the colloblasts-special catching cells having inside the spical felaments and special gluing substance to immobilize the potential preys.

It moves due to beating of cilia (tentillia) covering the surface of its locomotive comb flappers. The animal swims its mouth ahead mainly up or sometimes down. Its locomotion is controlled by its nervous system and by its apical statocyte. The subepidermal net of nervous system is located mainly under the rows of comb flappers.

Mnemiopsis leidyi is self-fertilizing hermaphrodite. It possesses gonads containing both the ovary and the spermatophore bunches in their gastrodermis. The gonads are situated along eight meridianal canals of its gastrovascular system. They are fixed between the ctenes. The rows of spermatophores spread along the meridianal canals. The rows of ovaries are fixed reciprocally in the neighboring canals. Gonads are forming in the central their parts beginning from the statocyst's level to the oral side (Zaika and Revkov, 1994). In the auricule canals only ovaries were observed. They form their 12 rows stretched along the main axis of the body. In the gonads fixed along the meridional canals in the intervals between ctenes usually are present one spermatophore and between 1 to 4 eggs, while in the auricular gonads there is one egg present. The specimens 5-7 cm long have 100-140 ctenes in their subsaggital rows spreading along the lobe surfaces, while in the shorter subtentacular rows their numbers are less - between 55-90. Such a specimen carries some 150 eggs along each meridianal canal and over 100 of them - in each auricular canal. Total numbers of simultaneously forming eggs depends of food availability and on temperature.

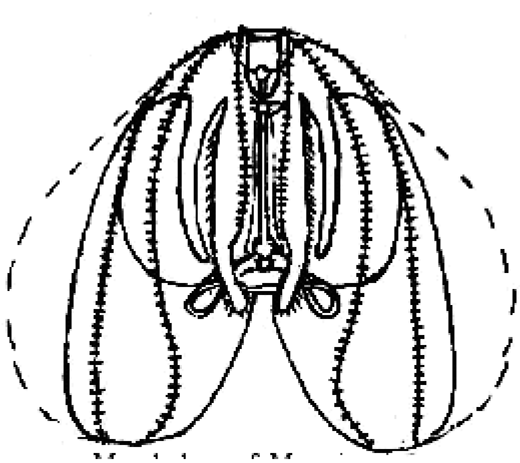


Figure 2.3 Morphology of Mnemiopsis leidyi in northern Caspian (from Shiganova et al., 2001a).

2.5.1 Luminescence of *Mnemiopsis leidyi*

Mnemiopsis is remarkably phosphorescent (Moore, 1924). The seat of the phosphorescence is confined to the rows of locomotive flappers (Agassiz, 1860). They are extremely sensitive and a slightest shock to the jar in which the ctenophores are kept is sufficient to make them plainly visible by the light emitted from the eight phosphorescent ambulacums. The light producing cells are fixed in the meridional canal, being asymmetrically located with respect to the axis of the canal, as viewed perpendicular to the plane of the comb plates. A group of cells can be identified in stained a section that is located below testicular tissue on the sidewall of the meridional canal being separated from the lumen of the canal by a layer of gastrointestinal cells (Moore, 1924).

2.5.2 Intraspecific forms

Some specimens of this ctenophore collected in the Black Sea have small papillae on their body surface, same as had been described by Fewkes (1881) during the primary description of *M. leidyi*. The morphology of this ctenophore in the Black Sea appears to be rather variable; they can be more or less transparent, mainly in dependence on ctenophore's size. With increase of body size transparence decreases, the largest individuals attain 150-180 mm in the Black Sea (Shiganova *et al*., 1998). Shiganova *et al*. (1998) and Roohi (2000) did not find papillae on their body surface of Caspian *Mnemiopsis* and they are more transparent due to their smaller size.